GROOVED SHAFT MEMBER AND ASSOCIATED TURBOCHARGER AND METHOD

FIELD OF THE INVENTION

The present invention relates generally to shaft members such as bearings, spacers, washers, and shaft shoulders that can be used in turbochargers and other devices, and more particularly, shaft members having a plurality of generally radial grooves on at least one surface for providing fluid communication.

BACKGROUND OF THE INVENTION

Bearings and other shaft mountable members are used in a variety of devices including turbochargers. In a conventional turbocharger, a turbine and a compressor are positioned at opposite ends of a center housing, and a shaft extends through the center housing to connect the turbine and compressor. The shaft is rotatably supported within the center housing by one or more bearings. The center housing typically defines a passage defining an inlet and outlet for circulating oil to and from the bearings. Radially extending holes can be provided in the bearings or other members mounted on the shaft, such as a spacer disposed between two bearings. The oil can flow through or between the bearings or other shaft mounted members and thereby circulate from the inlet of the housing to the shaft, and then back through or between the bearings or other shaft mounted members to the outlet. The oil provides lubrication between the various parts, e.g., between the rotating shaft and the bearings and other members thereon. The oil can also function as a coolant to convect thermal energy away from the parts.

The flow of oil radially between the adjacent surfaces of the bearings and other shaft mounted members provides lubrication and cooling to the adjacent members and increases the circulation of oil to the shaft. However, axial movement of the shaft mounted members can reduce the space between the adjacent members and prevent circulation of the oil therebetween. Such axial motion of the shaft mounted members can occur due to dynamic or hydraulic forces translated through the turbine, compressor, shaft, and the like. In addition, the circulation of the oil can be reduced if the pressure or temperature of the oil varies, as can occur during typical operation. As a result of the decrease in oil circulation, the members and/or the oil can become hotter, thereby reducing the effectiveness of the oil and increasing the wear on the parts.

In some cases, grooves can be provided on the axial face of the bearing for generating an axial force between the bearing and the adjacent member. For example, U.S. Patent No. 6,017,184 describes a bearing that is pinned to a bearing housing so the bearing system does not rotate. Thrust surfaces of the bearing are contoured to include radial grooves, lower flats, ramps, and upper lands. Oil is circulated radially through the grooves between the bearing and an adjacent member such that the oil causes a thrust force between the bearing and the adjacent member. In other conventional turbochargers, the grooves can be provided without ramps or other contours to achieve similar thrusting capacity between the members. Such grooved bearings provide improved oil circulation, but also complicate the manufacture of the bearings and/or the turbochargers, thereby increasing the cost. Further, the thrust generated by such bearings can be unnecessary or undesirable for particular applications.

There exists a need for an improved shaft member, such as a bearing, shaft, or shaft mountable member, for providing circulation of oil radially. Preferably, the shaft member should provide circulation under various conditions, including axial movement of the shaft or shaft mounted members and varying temperature or pressure of the oil. The shaft member should also enable

circulation of the oil without significant generation of thrust between the shaft member and adjacent shaft mounted members.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Having thus described the invention in general terms, reference will now be made to the accompanying drawings, which are not necessarily drawn to scale, and wherein:

Figure 1 is a section view illustrating a turbocharger according to one embodiment of the present invention;

Figure 2 is an elevation view illustrating a bearing according to one embodiment of the present invention;

Figure 3 is a section view illustrating the bearing of Figure 2, as seen along line 3-3 of Figure 2;

Figure 4 is a partial section view illustrating one of the grooves of the bearing of Figure 2, as seen along line 4-4 of Figure 2;

Figure 5 is a perspective view illustrating the bearing of Figure 2 and a die for forming the grooves therein according to one embodiment of the present invention;

Figure 6 is a perspective view illustrating a shaft mountable washer according to another embodiment of the present invention; and

Figure 7 is a perspective view illustrating a shaft according to yet another embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention now will be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all embodiments of the invention are shown. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will

satisfy applicable legal requirements. Like numbers refer to like elements throughout.

Referring now to the figures and, in particular, Figure 1, there is shown a turbocharger **10** according to one embodiment of the present invention having two shaft mountable members **50a**, **50b** and, in particular, journal bearings. It is understood that the shaft mountable members **50a**, **50b** of the present invention can be used with devices other than turbochargers, including compressors, motors, engines, and other rotational devices.

As illustrated in Figure 1, the turbocharger **10** includes a compressor wheel **12**, a turbine wheel assembly **14**, and a shaft **16** extending therebetween. The compressor wheel **12** and the turbine wheel assembly **14** are each rotatably mounted in a compressor and turbine (not shown), respectively, and configured to rotate with the shaft **16**. The shaft **16** extends through a center housing **30** that is positioned between the turbine wheel assembly **14** and the compressor wheel **12**. In particular, the shaft **16** extends through the two bearings **50a**, **50b** and a spacer **70** therebetween that are positioned within a cavity **32** defined by the center housing **30**. A thrust collar **18** is also provided on the shaft **16**. The thrust collar **18**, which rotates with the compressor wheel **12** and the shaft **16**, is axially restrained by a u-shaped thrust bearing **20** that is connected to the center housing **30** by a screw **21**. A backplate **15** is disposed between the center housing **30** and the compressor wheel **12**.

In operation, the compressor wheel **12**, turbine wheel assembly **14**, and the shaft **16** rotate in unison at speeds that can reach or exceed 100,000 RPM. The center housing **30** defines a fluid passage **34** having an inlet **36** and an outlet **38** for circulating oil or another fluid for lubricating and/or cooling the members in the cavity **32** of the center housing **30**. A pump and a cooler (not shown) can be provided outside the center housing **30** for circulating the oil and cooling the oil for re-circulation through the housing **30**. The oil is circulated through the inlet **36** to a main passage **40**, and therefrom to the cavity **32** and, hence, an outer surface of the bearings **50a**, **50b** and/or the spacer **70**. In particular, connection

passages **41**, **42**, **43** extend from the main passage **40** to the thrust bearing **20** and the first and second journal bearings **50a**, **50b**. Thus, oil flows from the main passage **40** to the thrust bearing **20** via the first connection passage **41**. Oil from the main passage **40** also flows through the second and third connection passages **42**, **43** to the first and second bearings **50a**, **50b**, respectively.

As shown in Figures 2 and 3, each bearing **50a**, **50b** has a body portion **52** that defines first and second sides **54a**, **54b** and a main bore **60** extending therebetween. The bore **60**, which can be circular in cross section, is configured to receive the shaft **16,** which rotates relative to each bearing **50a**, **50b**. In addition, the bore **60** can define portions of different diameters, e.g., first portions **60a** adjacent each side **54a**, **54b** and a second, narrower portion **60b** between the first portions **60a**, as shown in Figure 3. Each bearing **50a**, **50b** can also define one or more radial bores **58** that fluidly connect the main bore **60** to an outer surface **62** of the bearing **50a**, **50b**. For example, each bearing **50a**, **50b** can define four radial bores **58**, which are configured to successively connect to the respective connection passage **42**, **43** as the bearings **50a**, **50b** rotate so that oil can be delivered from the main passage **40** to the radial bores **58** of the bearings **50a**, **50b**.

The sides **54a**, **54b** of each bearing **50a**, **50b** can define a generally planar surface, or face **56a**, **56b**, which is configured to rotate against an adjacent member on the shaft **16** such as the spacer **70**, thrust collar **18**, or turbine wheel assembly **14**. The face **56a**, **56b** of each side **54a**, **54b** can extend radially from the bore **60** to the outer surface **62** of the bearing **50a**, **50b** or to a relief **64a**, **64b** connecting the face **56a**, **56b** and the outer surface **62**. As shown in Figures 2 and 4, each side **54a**, **54b** of the bearing **50a**, **50b** defines a plurality of grooves **66** extending radially between the bore **60** and an outer perimeter of the respective side **54a**, **54b**. For example, the grooves **66** can extend radially outward to the outer surface **62** or to the relief **64a**, **64b** of each side **54a**, **54b**. The grooves **66** provide a fluid passage between the bore **60** and the outer surface **62** so that fluid can flow between the bore **60** and the outer surface **62** through the grooves **66**.

For example, as illustrated in Figure 1, the oil can enter the center housing through the inlet **36** and flow into the main passage **40** and each of the connection passages **41**, **42**, **43**. From the first connection passage **41**, the oil flows to the thrust bearing **20**, thereby lubricating and cooling the thrust bearing **20**, and therefrom to the outlet **38**. From the second and third connection passages **42**, **43**, the oil flows to the respective bearing **50a**, **50b**, flowing radially inward through the radial bores **58** as the bores **58** rotate into fluid communication with the connection passages **42**, **43**. The oil can flow axially through the bores **60** of the bearings **50a**, **50b**, i.e., along the axial direction of the shaft **16** toward the sides **54a**, **54b** of each bearing **50a**, **50b**. The oil can then flow radially outward from the shaft **16** through the grooves **66** and to the outer surface **62** of each bearing **50a**, **50b**. Advantageously, flow through the grooves **66** is not restricted, even if the bearing **50a**, **50b** is urged against the adjacent member, i.e., the spacer **70**, thrust collar **18**, or turbine wheel assembly **14**. Once dispensed from the radial grooves **66**, the oil can flow through various drain passages **37** and through the outlet **38** of the housing **30**. Oil proximate to the shaft **16** can also flow radially outward through a bore **71** extending through the spacer **70** perpendicular to the shaft **16**, and then through the drain passage **37** to the outlet **38**. It is understood that the oil can alternatively circulate along other routes in other embodiments of the invention, and in some embodiments, the oil can flow radially inward through the grooves **66**.

According to one advantageous embodiment of the invention, the grooves **66** are formed by pressing a die against the bearing **50a**, **50b** or otherwise knurling the surfaces **56a**, **56b** of the bearing **50a**, **50b** to form the grooves **66**. For example, Figure 5 illustrates a die **80** that defines a plurality of radial ridges **82** that correspond to the desired shape and configuration of the grooves **66** in the bearing **50a**, **50b**. The die **80**, which can be formed of steel or another material that is preferably harder than the bearing **50a**, **50b**, can be pressed against the bearing **60** manually or with a hydraulic, pneumatic, or electric actuator (not shown), i.e., in the direction **84** as shown. If the grooves **66** are to be formed on

both faces **56a**, **56b** of the bearing **50a**, **50b**, two dies **80** can be pressed against the opposite sides **54a**, **54b** of the bearing **50a**, **50b** at the same time. Alternatively, a single die **80** can be successively pressed against the two sides **54a**, **54b** of the bearing **50a**, **50b**. The grooves **66** can also be formed by other methods such as milling the bearing **50a**, **50b** using a computer numerical controlled (CNC) milling machine, but it will be appreciated that the grooves **66** can be formed relatively quickly and, hence, at relatively low cost, by pressing the grooves **66** using the die **80** or a similar other form.

The grooves **66** are preferably structured so that fluid flow through the grooves **66** during operation does not generate significant thrust loading on the adjacent member, such as the thrust collar **18**, spacer **70**, or the turbine wheel assembly **14**. For example, each face **56a**, **56b** of the bearing **50a**, **50b** can define at least about 15 grooves, e.g., about 30 grooves **66**. Each groove **66** can have a depth that is less than about 0.025 inches, e.g., about 0.02 inches. Similarly, each groove **66** can define a width of about 0.02 inches, though the grooves **66** can define other widths in other embodiments. Thus, the combined cross-sectional area of the grooves **66** on one of the faces **56a**, **56b** can be at least about 0.003 square inches. Each groove **66** can define a variety of cross-sectional shapes, including a half-circle or other arc, a v-shape, a rectangular slot, and the like. The faces **56a**, **56b** defining the grooves **66** can be otherwise planar. As shown in Figures 2-4, both sides **54a**, **54b** of the bearing **50a**, **50b** define the grooves **66**, but in other embodiments, the grooves **66** can be defined in only one side **54a**, **54b** of the bearing **50a**, **50b**.

The bearings **50a**, **50b** can be used in devices other than compressors and turbochargers including, for example, motors and engines, electric, hydraulic, and pneumatic rotational appliances and devices, and the like. Further, the grooves **66** can be provided on shaft members other than bearings, such as shaft mountable members including spacers and washers. For example, Figure 6 illustrates a washer **90** according to another embodiment of the present invention. The washer **90** defines a body portion **92** having first and second sides **94a**, **94b**, one or both

of which can define a plurality of grooves **96**. The washer **90** also defines a bore **98** for receiving a shaft such as the shaft **16** of the turbocharger **10** described above. Thus, the washer **90** can be configured proximate other members on the shaft so that the grooves **96** in the washer **90** provide fluid communication between an outer perimeter **100** of the washer and the bore **98**. Similar to the bearings **60** described above, the washer **90** preferably provides fluid communication without generating significant thrust loading on the adjacent member(s). The grooves **96** of the washer **90** can be formed using the die **80** described above or using a similar structure.

In addition, the shaft member of the present invention can be a unitary or integral part of a shaft. For example, Figure 7 illustrates a shaft **110** for receiving one or more members, such as bearings, spacers, and the like, that are rotatable relative to the shaft. The shaft **110** includes first and second portions **112, 114** having outer surfaces **116**, **118** of dissimilar diameters. In particular, the diameter of the first portion **112** is smaller than that of the second portion **114** such that the first portion **112** can receive a shaft mountable member **130** (shown in dashed lines for illustrative clarity). The shaft **110** defines a shoulder surface **120** that extends radially between the outer surfaces **116**, **118** of the first and second portions **112**, **114**. The shoulder surface **120** defines a plurality of grooves **122** extending radially between the outer surfaces **116**, **118** of the first and second portions **112**, **114**. Similar to the grooves **122** of the bearing **50a**, **50b** and other shaft members described above, the grooves **122** provide a radial fluid passage between the shoulder surface **120** and the adjacent relatively rotatable member **130** such that fluid is communicated through the grooves **122** without generating significant thrust loading between the shoulder surface **120** and the relatively rotatable member **130**. The number, size, and configuration of the grooves **122** can be similar to those described above, and the grooves **122** can be formed by pressing a die against the surface **120**. Further, the shaft **110** can define more than one shoulder surface, each of which can define any number of the grooves.

Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. For example, it is appreciated that each of the components of the present invention can be formed of any conventional structural materials including, for example, steels and other metals. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.